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EXPANDING THE CONCEPT OF TECHNOLOGY TRANSFER: OPPORTUNITIES FOR GOVERNMENT-INDUSTRY COOPERATION*

by

Richard L. Chapman
Senior Research Scientist
Denver Research Institute

The Denver Research Institute recently completed an exploratory study for the National Aeronautics and Space Administration (NASA), the purpose of which was to examine how NASA might accelerate and expand the application of NASA-derived technology for other civil uses in the United States. Based upon that study and other research, this paper deals with five questions which are significant in addressing the question of "How can Federal efforts promote technological innovation?" These questions are: (1) Why are Federal efforts to stimulate commercial application of technology important? (2) What public policies have an impact upon technological innovation? (3) How does industry view current Federal efforts to stimulate the transfer of technology? (4) What have we learned from past efforts to transfer technology? and (5) What ought to be the direction of future efforts?

Why are Federal Efforts to Stimulate the Commercial Exploitation of Technology Important?

We appear to be at a point in history where a convergence of several factors suggests that heightened efforts by the Federal government

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to exploit technology for commercial purposes can be both timely and effective. For example, William F. Mill, President of SRI International, recently observed that the U.S. is on the verge of a major "wave" of technological exploitation.

> Many of the technologies of the 1960s and early 1970s were based on pre-war science. . . . There is a big backlog of post-war science now maturing. We are seeing just the leading edge of its commercialization.[1]

There is increasing recognition that research is a key factor in economic growth. Recognized economists such as Edwin Mansfield, Robert Solo, and Edward Denison, for example, have conducted numerous econometric studies that, on balance, demonstrate the positive effect of research and development upon productivity increases.[2] Mansfield, in testimony before the House of Representatives Committee on Science and Technology in 1976 made a strong connection between research and development expenditures and the economy,

> . . . our science and technology policies can have important long-run effects, assuming that proper fiscal and monetary policies are adopted. In particular . . . there is a great deal of evidence that R&D expenditures are directly related to the rate of productivity growth (allowing for a time lag). Since the increases and rate of productivity growth can offset increases in labor, materials, and other costs, they can tend to moderate the inflation rate. Thus, our technological policies can have a noteworthy, if secondary, influence on inflation, as well as a major influence on our rate of economic growth.[3]

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[1] As quoted in Business Week, April 18, 1983, page 79.

[2] For example, see Braustein, et al., "The Economics of R&D" in Management of Research and Innovation, B.V. Dean and J.L. Goldhar, New York: North-Holland Publishing Company, 1980, page 28.

[3] Mansfield, Edwin, testimony before the U.S. House, Committee on Science and Technology, Subcommittee on Domestic and International Scientific Planning and Analysis, in Federal Research and Development Expenditures and the National Economy, hearings held April 27, 28, 29, and May 4 and 5, 1976, Washington, DC: U.S. Government Printing Office, 1976, p. 49.

A third factor which has been dramatically brought to the attention of the American public in the past few years is the increasingly successful competition in high technology from such countries as Germany, France, and Japan. As early as 1980, Congressional hearings revealed that U.S. export shares in manufacturing commodities had trend declines of nearly three times that of Japan and West Germany.[4] One factor in meeting such competition is for U.S. industry to exploit more rapidly and more fully advances in technology.

The convergence of these factors and their impact on the U.S. economy suggest the desirability of reviewing current practices and policies that affect technological innovation.

What Public Policies Have an Impact Upon Technological Innovation?

The most important factor in the short run affecting the application of technology in the civil sector is the general state of the economy. As the economy slowed down in recent years, the growth of research and development expenditures slowed, venture capital was restricted, and private firms generally shortened their perspectives with respect to investment, capitalization, and risk-taking in general. To paraphrase one investment specialist, ". . . the action that would have the largest impact on industry's willingness to invest in the application of technology is the reduction of interest rates to under 10 percent and an upswing in the general economy." Perhaps just as important, however, is the need for industry to be aware of potentially applicable new technology at a

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[4]U.S. Congress, House, Joint Economic Committee, U.S. Export Competitiveness, Washington, DC: U.S. Government Printing Office, 1980. July 29, 1980, p. 25.

level of detail where value versus risk can be well understood. Whereas in the past applicable technology innovations usually occurred within a company, now they frequently occur outside, and cooperative efforts are required to assure timely awareness.

However, apart from the economy in general, there are seven major policy areas considered to have an impact on technological innovation. These are: tax policy, patent policy, antitrust policy, regulatory policy, research and development support policy, organizational conflict of interest policy, and freedom of information policy. Each of these has the potential to inhibit or facilitate the application of technology. Our review suggested that current law and policies in these seven areas generally do not present overwhelming obstacles between industry and government in the transfer of technology, though improvements can be made in each issue area. However, three of these policy areas deserve continued evaluation as they repersent areas in which significant improvement might be made as new avenues for government-industry cooperation are expanded: patent policy, antitrust policy, and organizational conflict of interest policy.

Recent changes in the patent law, and improvements in the administration of the Patent and Trademark Office liberalized the acquiring of patents for work done under government contract, and have accelerated the process of patenting new innovations. Nearly three years of experience under Public Law 96-517 (Patent and Trademark Amendment of 1980) has not fully supported the thesis that such liberalization would result in substantially higher levels of patent activity, thereby signifying

greater exploitation of new technology.[5] Substantial care needs to be exercized in future changes to recognize differing needs of Federal agencies as well as practical means to reduce barriers that appear to inhibit effective commercialization.

Cooperative activities, either between private industry and government, or between private businesses, have been rare enough that antitrust considerations were of minor consequence. A principal exception was when the Federal government prohibited major automakers from conducting cooperative research to meet emission standards under the air quality control regulations. This stance may be shifting in recognition of a need to remove restraints not imposed in other nations. Recently, the Justice Department, with the encouragement of the Department of Commerce, appears to be allowing greater flexibility for such arrangements. For example, the Justice Department's approval of the Microelectronic and Computer Technology Corporation (MCC)--which is a consortium of major electronics firms--suggests a possible change in direction.

The issue of organizational conflict of interest is a deep-seated concern that no special benefits be provided at public expense which gives any one firm a competitive advantage over other firms. Increased cooperation between government agencies and private companies will necessarily be subject to intense scrutiny to avoid such special advantage.

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[5]Data furnished by the National Aeronautics and Space Administration for years 1981 and 1982. There was no increase in patent activity by small business, nonprofit or university entitites, and a substantial decline in such activity on the part of individuals or small businesses. Several agencies have indicated substantial increases in patent activity, particularly by universities, although specific data has not been made available.

Because there is no uniform government policy regarding organizational conflict of interest, agencies venturing into cooperative arrangements with private industry will have to be especially sensitive to this issue.

How Does Industry View Current Federal Efforts to Stimulate the Transfer of Technology?

Nearly three dozen corporate executives were interviewed in the course of DRI's study. They represented a variety of businesses including high technology (electronics, aerospace, and medical equipment), automobile and heavy manufacturing, engineering and product development, and the investment capital field. Both large and small firms were represented. The purpose was to obtain perspectives from industry on technology transfer efforts and the competitive challenges facing the United States. Areas of discussion included changes in the pattern of technology acquisition over the last 20 years, influences of foreign competition, channels of technology transfer, industrial patent policy, university linkages, and barriers or incentives to the transfer of technology.

The structural differences between government and industry stand out clearly--one is politically responsible and the other is responsive to market forces. Even though these differences generate skepticism among industrial managers, there remains strong interest in the possibilities of cooperation and a realization of what might be gained through searching for better ways to transfer or exchange technology.

Industry representatives generally believe that government-generated technology includes many innovations that would be attractive

to industry. Yet, there is also a feeling that government technology often is too expensive for commercial application without substantial adaptation. Industry leaders stress that this adaptation, and in many cases redesign and engineering costs, often seem to be more than originally anticipated, causing the shelving of worthwhile innovations. Such costs of adaptation often were cited as being up to ten times the cost of the basic technology development.

The more risk that the government can assume in a product or process development the more likely that it will be that a firm will be in a position to accept the remaining cost risks of introducing a process or product into the commercial mainstream.

A continuing problem of substantial importance for industry is generating capital for innovation. The most pessimistic view expressed was that the "less government work a company engaged in, the better the chances for private venture capital for innovation." Particularly, in the case of small businesses, there is a shortage of capital for applying government-generated technology. Because small companies often are not aware of areas of government interest, they miss out on innovative ideas and chances of contract awards that go to larger firms. Even highly qualified small engineering development firms cannot afford to keep current with the vast technical needs of the Federal agencies, and cannot afford to risk investment in technology outside their narrow specialty areas. To some extent this is being changed through the Program for Small Business Innovative Research.

A widespread concern among industrial leaders is that Federal agencies do not seem to be sensitive to or aware of the kinds of constraints with which industry must deal--such as a competitive economic environment, problems of marketing and competition, and the protection of proprietary information. Industry measures innovative success in terms of profit dollars generated within a specific payback period, whereas Federal laboratories' measure of success is more in terms of technical objectives met. The often adversarial relationship between government and industry needs to be overcome. There is a traditional perception, greatest in nonaerospace and the commercial sector, that government does not understand the needs of industry. One example is the development of one of a kind or limited numbers of space craft; given that highly specialized and custom crafted expertise the obvious questions asked by industrialists are: "How can Federal scientists and engineers understand the problems of manufacturing 150 million silicon chips?" or "What do they know of the quality control problems of an automotive assembly line?"

The substantial difference in the institutional perspective between persons in industry and those in government requires both patience and effort to be overcome. If industry and government are to cooperate in the transfer of technology, the relationship is most effective when it is one of equals, with government scientists and engineers learning from counterparts in industrial laboratories, and vice versa. Informal networks of personal communication are favored. This is true both within and outside a corporation. It was acknowledged that modest changes and

ideas can be generated by paper-based information systems, but major transfer of information rarely occurs without sustained individual attention. Respondents often noted that technology transfer does not appear to be a function of high priority in government, given its generally low visibility within the bureaucracy and very limited resources.

In spite of these obstacles two considerations suggest that, currently, there are significant opportunities for cooperative efforts between Federal government and private industry which may not have been as clearly present before. For example, there has been a marked trend in U.S.industry away from a traditional reluctance to borrow ideas from others, particularly from outside the corporation. Even large, high technology firms no longer are able to meet their own technology requirements solely through in-house efforts.

Second, there is substantially increased awareness within the private sector that technological capability in Federal agencies has not been adequately tapped, and that the potential for its use in commercial area needs to be given serious consideration. Such awareness, however, does not translate automatically into the transfer of technology. Both industry and government need to be more fully informed of each other's operating environments, opportunities and limitations if the necessary rapport is to be developed to facilitate effective transfer.

In summary, there remains a substantial gap in understanding between officials of government agencies and officials of industrial companies with respect to their mutual interests and their respective operating problems. Without clearer agency priority for technology

transfer functions, and higher visibility, it is unlikely that industry executives will take programs to foster such transfer very seriously. In spite of such obstacles, there appears to be an increasing interest on the part of corporate officials about exploring the possibilities for greater cooperation with government agencies for the purpose of the transfer of technology and technological exploitation.

What Have We Learned from Past Efforts to Transfer Technology?

Nearly 20 years of literature and case studies on the process of technology transfer provide a rich background of material regarding the characteristics of successful transfer experiences. No single transfer had all of the following characteristics, and many undoubtedly succeed for reasons other than those presented here. However, the list simply indicates those factors which more often than not have been present in successful transfer experiences from Federal laboratories:

- Users had ready access to the necessary information.
- A market existed for the technology application.
- Transfer did not directly disrupt existing social systems.
- Support requirements (i.e., the user's technical capabilities, facilities, resources, etc.) were not excessive.
- Advocates of transfer were trusted sources of information.
- A limited number of individual approvals was required to adopt the technology.
- The adopted technology did not replace a standardized item where the costs of changeover were high (unless the benefits far exceeded the cost).
- Adoption required incremental rather than wholesale change.
- Adoption did not dramatically change the relationship between suppliers and customers.

- The Federal government supported adoption (through technical assistance, loans, etc.).
- The Federal government subsidized the market (particularly where the Federal government was itself a customer--e.g., aircraft, electronics, etc.).

A review of technology transfer programs in Federal mission-oriented agencies and discussions with senior officials in seven Federal laboratories suggest a number of principles which, if followed, should make future efforts along these lines more successful.

One of the first principles is the need to institutionalize technology transfer. This means that the process must be woven into the general fabric of the agency or agencies involved--to the extent that this function becomes a regular part of daily activities rather than a secondary "add-on" activity. This requires some formal organizational structure with visibility and influence within the agency. At the same time, it is clear that the nature of the technology transfer process thrives upon a certain degree of serendipity and therefore should not be "over structured" lest it substantially detract or reduce actual transfer efforts. To the extent an agency or organization "bureaucratizes" the technology transfer process, it will be undercut, leaving only a trail of paper and few real results.

Those with direct experience in technology transfer attest to the importance of networks of personal contacts as a principal means for becoming aware of the existence of new technology during the initial stages of information exchange. Again, this suggests that the process cannot be rigidly organized as is the temptation in most bureaucratic organizations.

Technology is most likely to be successfully transferred in those instances where such efforts are focused on areas of technological strength within the organization which has the technology for transfer. At the same time, it should be recognized that neither a government agency nor an industrial concern is going to continue in such a relationship without it being a two-way street, where each participant receives some technological benefits. Both the nature of the client group and its potential users, having a common interest in the technology, clearly have a substantial influence on the success of technology transfer. For example, the Department of Agriculture (USDA) has been successful in transferring agricultural technology to the U.S. farm community. This success may be attributed, at least in part, to the nature of the client group--i.e., fragmented, engaged in atomistic rather than rivalrous competition, visible and well organized, playing a large role in setting agency research priorities, generally educated and prone to experiment with new technology.[6] In addition, USDA (through its highly decentralized system of county agents) has developed a close working relationship with these potential users of new technology. The same high degree of success would not be possible with a less cohesive, less well defined client group in which members engaged in more direct competition with one another. Obviously, the degree of difficulty increases when the potential users of technology are not a part of or related to the agency's traditional client groups.

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[6]Granville, W. Hough, Technology Diffusion: Federal Programs and Procedures, Mt. Airy, Maryland: Lomond Books, 1975, pp. 77-103; U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Science, Research, and Technology, Hearings on Implementation of P.L. 96-480, The Stevenson-Wydler Technology Innovation Act of 1980, Washington, DC: U.S. Government Printing Office, 1982, pp. 56-60.

Again, related to the technology is the nature and focus of the agency mission. In the past, the more specialized agency mission (and the more divorced that mission from the needs of the economy), the less likely the agency will be to find and diffuse the technology to the general economy. For example, much of the work performed by the Department of Defense (DOD) and the nuclear weapons portion of the Atomic Energy Commission (AEC) focused on very specific economic sectors. The technologies developed by these agencies tended to be costly, risky, inapplicable or inaccessible. These experiences can be contrasted with those of agencies such as the USDA, the Department of Energy (commercial nuclear and non-nuclear components), and the Small Business Administration (SBA). Recent efforts by DOD and others to increase their role in technology transfer appear to have reduced, although not eliminated, the importance of the agency mission as a factor in the transfer process. A specialized agency mission with limited connection to the general economy need not present a permanent obstacle to effective technology transfer.

Since there are substantial differences in approach and perspective on the part of public agencies and most major industrial organizations, it is recognized that opportunities for cooperative effort may be most easily developed in conjunction with a third party, such as professional organization or a unviersity where "neutral ground" exists for cooperative efforts. In such cases, each participant brings something to the table, contributing to a joint effort.

Finally, a public agency must have both political and social support for any significant, organized technology transfer activity if such efforts are to be sustained. Continuity of effort is important, but rarely has been achieved for any length of time.

What Ought to be the Direction of Future Efforts?

The technology transfer function will continue to be "an on-again, off-again" activity in most Federal agencies unless serious action is taken to make it an integral part of each agency's continuing responsibility. This will require some degree of continuity in staffing, funding, and recognition. One illustrative indicator of when this "institutionalization" is beginning to stick will be that time when a technical program manager's performance evaluation includes the technology transfer function.

Concurrent with specific steps to bring the technology transfer process within the mainstream of an agency's activity are four actions which can facilitate this process and give added emphasis and strength to those technology transfer activities already undertaken.

The first is to provide a leadership focus at the level of agency headquarters in each agency which has a significant research program. The Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480) provides the stimulus for such action, at least at the minimum level of providing an agency focal point for reporting required under the act and some minimum coordination. However, such designations appear too often to vest such responsibilities in a headquarters official on the basis of "in addition to other duties" so that there is rarely a "champion" for this function on a continuing basis. The function requires more than a mail drop and a telephone number.

Second, since the transfer of technology is most active and successful at the laboratory level, substantial program operational authority needs to be delegated to that level and given support by agency headquarters. This has an additional advantage of providing laboratory

level officials with some bargaining power in dealing with their own laboratory management. The Federal Laboratory Consortium for Technology Transfer is an excellent example of determined grass roots effort. It is hampered by the lack of leadership continuity--not at the laboratory--but often at the agency level.

Third, means must be provided for closer cooperation with the private sector. For example, highly recognized technical experts from private industry might be given access to the technological planning process of an agency as a means for identifying technology trends of interest to both the agency and industry. Agencies can seek expanded opportunities for joint activities in one or another stage of research and development. Or, agencies might join with industrial counterparts, universities, or independent research laboratories in ad hoc consortia for research and technology exchange. Many variations are possible, but any one of them will require conscious, positive effort to reach out to the private sector and the university community.

NSF has supported such arrangements, and industry of all kinds participate in a wide variety of such efforts. These include relatively well funded efforts to establish "centers of excellence" (e.g., the Semiconductor Research Cooperative Program, with a target budget of $40 to $50 million).

Other programs relating to the center of excellence idea include such efforts where state government works with industry in funding a substantial effort such as that of Arizona State University in establishing the Center for Engineering Excellence, where nearly $30 million is involved in a state-industrial cooperative activity for microelectronic

and computer activities. Another variation is the university-sponsored liaison program, one of the better known ones being the Industrial Liaison Program at the Massachusetts Institute of Technology, where each participating company has a liaison officer to match its needs with the potential services provided by the liaison program. Another effort which has been underway since the early 1970s is the National Science Foundation Experimental R&D Incentives Program, which provided startup funds for research programs that had matching industry support. This gradually evolved into the University-Industrial Cooperative Research Centers Program. One of these programs was the Rensselaer Polytechnic Institute Center for Interactive Computer Graphics. Formed in 1977, the Center had an operating budget of $620,000 in 1982, of which industry support constituted $480,000. Another example of this type of ad hoc activity is the University of Illinois Fracture Control Program, in which a variety of industries participate in supporting research and development efforts at the university and in undertaking mutual projects and the exchange of research data.

Finally, throughout these efforts, maximum use should be made of the "natural" channels of technology communication, such as participation in professional organizations and conferences, publications in professional and trade journals, laboratory or plant visits, and the like. Agencies can more aggressively make known both their interests, current program activities, and areas of future interest through these types of channels to provide additional opportunities for linkages with scientist and engineer counterparts in the private sector.

What has been described above calls for a broader concept of what constitutes the full range of "technology transfer." It cannot be limited solely to programs for distribution of printed material, though that is an important element. It cannot be limited to the use of "technology agents" whether they be in laboratory settings or in potential user facilities, though they do have an important role to play. It cannot be limited to the specific projects of advanced development directed toward the commercial economy, though these are important. It can operate best when combinations of these various means of transfer are incorporated within a conscious policy toward facilitating technology transfer and the exchange of technical information as widely as possible--as a continuing responsibility of every Federal agency which conducts research and development for public purposes, whether they be general or specific. Perhaps most important of all, it means creating a management and operating environment both at an agency headquarters and in its laboratories and field activities whereby working scientists and engineers are encouraged to reach out and exchange information and interact with their peers in American industry, with the recognition that this behavior will be rewarded rather than ignored or punished.

Can Federal efforts promote technological innovation? Yes, they can, and one of the principal tools for accomplishing this is a broader, more organized, conscious program to facilitate technology transfer between industry and government. A recent editorial, appearing in an aerospace company's in-house magazine, pleaded the case for working at technology transfer by combatting the false myths many hold regarding

technology transfer.[7] The myths are: (1) that industry automatically "gobbles up" new technology as soon as it is revealed, (2) that a "better mousetrap" is self-evident and doesn't need selling, and (3) that "exciting and valid" technology will "automatically" be transferred. All of these myths are founded on the erroneous belief that worthwhile transfer is a self-servicing system. The basic point is that a company or agency must be organized to enhance technology transfer if the right connections are to be made and technology most effectively applied--and this requires conscious effort throughout an organization. Yet is must be given leadership and facilitation, rather than hard control, lest this rather fragile process be buried in red tape.

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[7] TRW Electronics and Defense/Quest, Winter, 1982-1983, p. 65.